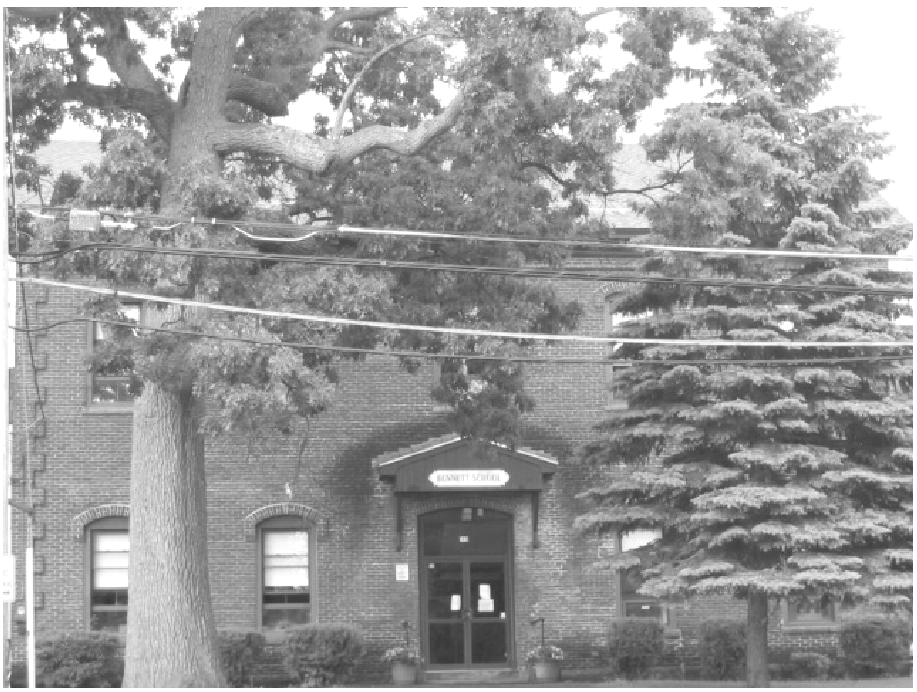
INDOOR AIR QUALITY ASSESSMENT

Bennett School
145 Pleasant Street
Leominster, MA 01453



Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Emergency Response Indoor Air Quality Program
September 2005

Background/Introduction

At the request of the Leominster Health Department, the Massachusetts Department of Public Health's (MDPH), Center for Environmental Health (CEH), provided assistance and consultation regarding indoor air quality at each of Leominster's public schools. These assessments were jointly coordinated through Chris Knuth, Director of the Leominster Health Department, and David Wood, Facilities Director for Leominster Public Schools (LPS). On June 14, 2005, Sharon Lee, an Environmental Analyst in CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program, conducted an assessment at the Bennett School, 145 Pleasant Street, Leominster, Massachusetts.

The Bennett School is a red brick building constructed in 1878 and contains 10 classrooms, a cafeteria/all purpose room, and offices. A separate modular building with two classrooms was added in 1983. Renovations to the main building (roof and floor replacement) were reportedly conducted in the summer of 2004. Windows are openable throughout the building. A number of windows in the building have been replaced. Remaining windows are reportedly on a capital repair list and will be replaced as funds become available.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector

(PID). CEH staff also performed a visual inspection of building materials for water damage and/or microbial growth.

Results

The Bennett School houses a pre-kindergarten and kindergarten student population of approximately 250 and a staff of approximately 35. Tests were taken under normal operating conditions. Test results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were elevated above 800 parts per million (ppm) in four of eighteen areas, including areas from both the main and modular buildings. However, it should be noted that the majority of areas surveyed in the main building with carbon dioxide levels below 800 ppm were sparsely populated, unoccupied and/or had windows open, which can greatly reduce carbon dioxide levels. Carbon dioxide levels would be expected to be higher with full occupancy and with windows closed.

Ventilation in the original school structure was initially provided to classrooms by a natural gravity ventilation system, which distributed rising heated air via a process known as the stack effect. The supply components to the system appeared to have been removed/sealed; the exhaust vents were left intact in the majority of classrooms surveyed (Picture 1). At the time of the assessment, these vents did not appear to be operating. LPS staff could not confirm when these elements last operated. Thus, in the main part of the building, there is no mechanical ventilation system. Fresh air is provided solely by openable windows. Of the rooms assessed in the main building, one room had elevated carbon monoxide levels, and it was the room with the greatest number of occupants.

Mechanical ventilation is provided to modular classrooms by rooftop air-handling units (AHUs). Fresh air is supplied to the classroom by ceiling mounted diffusers (Picture 2), and air is returned to the AHUs via ceiling mounted exhaust vents (Picture 3). Thermostats control each heating, ventilating and air conditioning (HVAC) system and have fan settings of "on" and "automatic". Thermostats were set to the "automatic" setting (Picture 4) in both of the modular rooms during the assessment. The "automatic" fan setting on the thermostat activates the HVAC system at a preset temperature. Once the preset temperature is reached, the HVAC system is deactivated. Therefore, no mechanical ventilation is provided until the thermostat re-activates the system. All areas in the modular building had elevated carbon dioxide levels, indicating inadequate air exchange in these areas. At the time of the assessment, the mechanical ventilation had cycled off.

To maximize air exchange, the MDPH recommends that ventilation equipment operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). It was reported by Mr. Wood that LPS has a contract with Pioneer Valley Environmental, Inc., an HVAC engineering firm that conducts preventive maintenance of HVAC equipment in all of Leominster's public schools. The preventative maintenance program consists of an annual assessment of all HVAC system components (e.g., univents, AHUs, pneumatic controls, thermostats). A detailed report is generated and provided to the LPS facilities department to address needs.

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information on carbon dioxide see Appendix A.

In the main building, temperature readings ranged from 82^{o} F to 87^{o} F (out door temperature was 82^{o} F), which were above the MDPH comfort guidelines of 70^{o} F to 78^{o}. In the modular areas, temperature ranged from 71 ^{o} F to 76 ^{o} F, or within the MDPH recommended temperature guidelines. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. It is often difficult to control temperature and maintain comfort without operating the ventilation equipment as designed. The original fresh air supply system to classrooms in the main building acted to pressurize each classroom by the flow of rising air from supply ducts. This pressurization is now absent due to the abandonment of this system. For the classrooms in the modular building, thermostats were set to automatic, thereby limiting the amount of fresh air supplied to classrooms.

The relative humidity measurements in the main building ranged from 47 to 77 percent, with a majority of areas assessed above the MDPH recommended comfort range of 40 to 60 percent for indoor air relative humidity. It should be noted that outdoor relative humidity that day was 69 percent. In the modular building, relative humidity ranged from 48 percent to 54 percent, or within the MDPH recommended relative humidity comfort range.

While temperature is mainly a comfort issue, relative humidity in excess of 70 percent for extended periods of time can provide an environment for mold and fungal growth (ASHRAE, 1989). Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

A few areas had water-stained ceiling tiles (Picture 5), which can indicate leaks from the roof or plumbing system. Water-damaged ceiling tiles can provide a source for mold and should be replaced after a water leak is discovered and repaired. Water-damaged ceiling and wall plaster were also observed throughout the school (Pictures 6 and 7). Although water-damaged ceiling plaster is not a source for mold growth, moistened dust trapped in spaces between the paint layers can become mold growth media.

Other sources for water penetration to the building were observed. Breaches were noted in and around the building and its windows. A rubber gasket for a classroom window was also failing (Picture 8). These breaches can serve as points for water entry into the building. Continued freezing and thawing of water during cooler months will serve only to further damage the frame. In addition, breaches can serve as points of entry or shelter for pests. The side paneling to a window bay was damaged. Since the panel is no longer intact, water can penetrate the building interior.

A number of breaches were seen around the building exterior (Pictures 9 and 10). Missing mortar around brickwork was noted in a number of areas. Damage to the modular classroom exterior wall was also observed (Picture 11). Holes, breaches, and seams are points through which water can penetrate the building, particularly under driving rain conditions. In addition, the gutter/downspout system was damaged/missing or improperly connected in some areas around the modular classrooms. Portions of the exterior wall were wet as a result of improperly connected downspouts (Picture 12). Excessive exposure of the building exterior to water can result in structural damage. Over time, these conditions can undermine the integrity of the building envelope and provide a means of water entry into the building by capillary action through foundation concrete and masonry (Lstiburek & Brennan, 2001).

Lastly, plants were observed to be growing against the foundation walls between cracks and in subterranean pits (Pictures 13 and 14). The growth of roots against exterior walls can bring moisture in contact with the foundation. Plant roots can eventually penetrate, leading to cracks and/or fissures in the sublevel foundation.

Other IAQ Evaluations

Indoor air quality can be negatively influenced by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion emissions include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, MDPH staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

The American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from six criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000a). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS levels (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. On the day of assessment, outdoor carbon monoxide concentrations were non-detect (ND) (Table 1). Carbon monoxide levels measured in the school were also ND (Table 1).

The US EPA has established NAAQS limits for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits to particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 microgram per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2000a). These standards were adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US

EPA proposed a more protective standard for fine airborne particles. This more stringent PM2.5 standard requires outdoor air particle levels be maintained below 65 μg/m^3 over a 24-hour average (US EPA, 2000a). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, MDPH uses the more protective PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations were measured at 86 μg/m^3 (Table 1). This PM2.5 measurement may be attributed to passing traffic on the main road. In addition, the outdoor PM2.5 concentrations for the greater Worcester, Massachusetts area the day of the assessment were moderate (51-100 μg/m^3) (AirNow, 2005).

PM2.5 levels measured within the school were between 38 to 104 μg/m^3, with the majority of measurements less than or about the level measured outside (Table 1). Frequently, indoor air levels of particulates can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulates during normal operation. Sources of indoor airborne particulate may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices, operating an ordinary vacuum cleaner and heavy foot traffic indoors. The PM2.5 levels measured in this building were generally consistent with the particulate level outside on the day of the assessment. The lack of mechanical ventilation in the building hampered air exchange and, hence, removal of airborne particulates.

Indoor air quality can also be negatively influenced by the presence of materials containing volatile organic compounds (VOCs). VOCs are carbon-containing substances that have the ability to evaporate at room temperature. Exposure to low levels of total VOCs

(TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. An outdoor air sample was taken for comparison. Outdoor TVOC concentrations were ND (Table 1). Indoor TVOC concentrations were also ND (Table 1).

Please note, TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC containing products. In an effort to identify materials that can potentially increase indoor TVOC concentrations, MDPH staff examined classrooms for products containing these respiratory irritants. Several classrooms contained dry erase boards and dry erase board markers, which may contain VOCs, such as methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999).

Cleaning products were found on countertops and in unlocked cabinets beneath sinks in some classrooms. These products contain VOCs and other chemicals that can be irritating to the eyes, nose and throat of sensitive individuals. These products should be stored properly and kept out of reach of students.

Pest attractants were identified within the building. Food-based projects and re-use of food containers were observed. Proper food storage is an integral component in maintaining indoor air quality. Food should be properly stored and clearly labeled. Reuse of food containers is not recommended since food residue adhering to the surface may serve to attract pests.

Conclusions/Recommendations

In view of the findings at the time of the visit, the following recommendations are made to improve general indoor air quality:

1. Consult an HVAC engineer concerning the operability of classroom exhaust vents (Table 1).
2. Use openable windows in conjunction with classroom exhaust vents to facilitate air exchange. Care should be taken to ensure windows are properly closed at night and weekends to avoid the freezing of pipes and potential flooding.
3. Set the thermostats in the modular classrooms to the fan "on" position to operate the ventilation system continuously during occupancy.
4. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
5. Ensure leaks are repaired, and replace water damaged ceiling tiles. Examine the area above and around these areas for mold growth. Disinfect areas of water leaks with an appropriate antimicrobial.
6. Remove plants from the wall/tarmac junction around the perimeter of the building.
7. Contact a masonry firm or general contractor to repair missing/damaged mortar on exterior brick to prevent water penetration, drafts and pest entry.

8. Seal areas around sinks to prevent water-damage to the interior of cabinets and adjacent wallboard. Install an appropriate backsplash to prevent damage to the wall.
9. Continue to replace remaining windows on the capital repair list and as funds become available. In the interim, re-seal loose window frames to prevent drafts and water penetration.
10. Store cleaning products properly and out of reach of students. Consider storing cleaning products in cabinets with childproof locks.
11. Store and label food appropriately. Refrain from re-using food containers.
12. Consider adopting the US EPA (2000b) document, "Tools for Schools", to maintain a good indoor air quality environment in the building. This document can be downloaded from the Internet at http://www.epa.gov/iaq/schools/index.html.
13. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. Copies of these materials are located on the MDPH's website: http://mass.gov/dph/indoor_air

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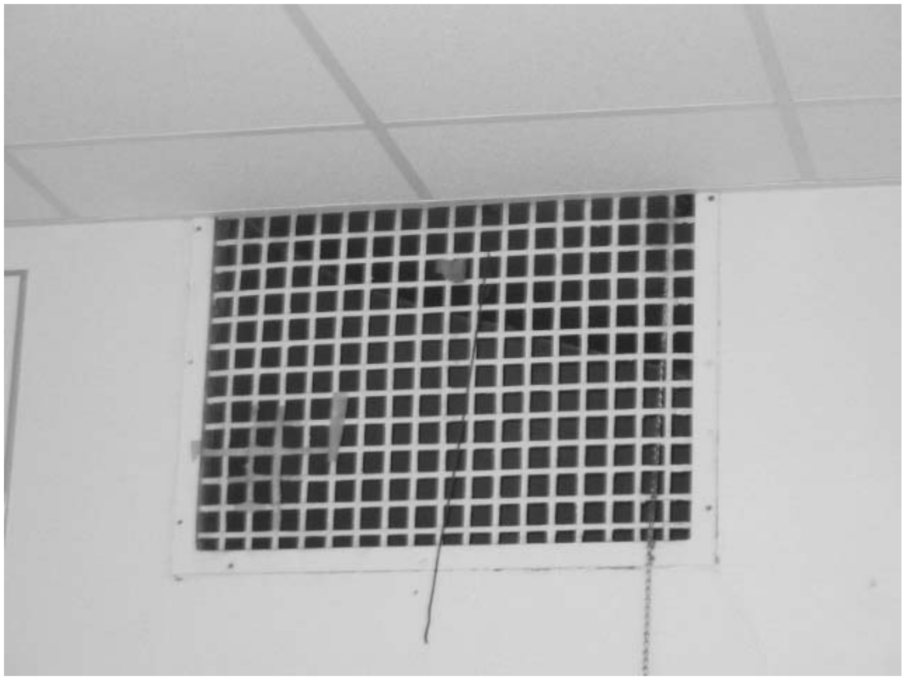
Picture 1



Wall exhaust vent

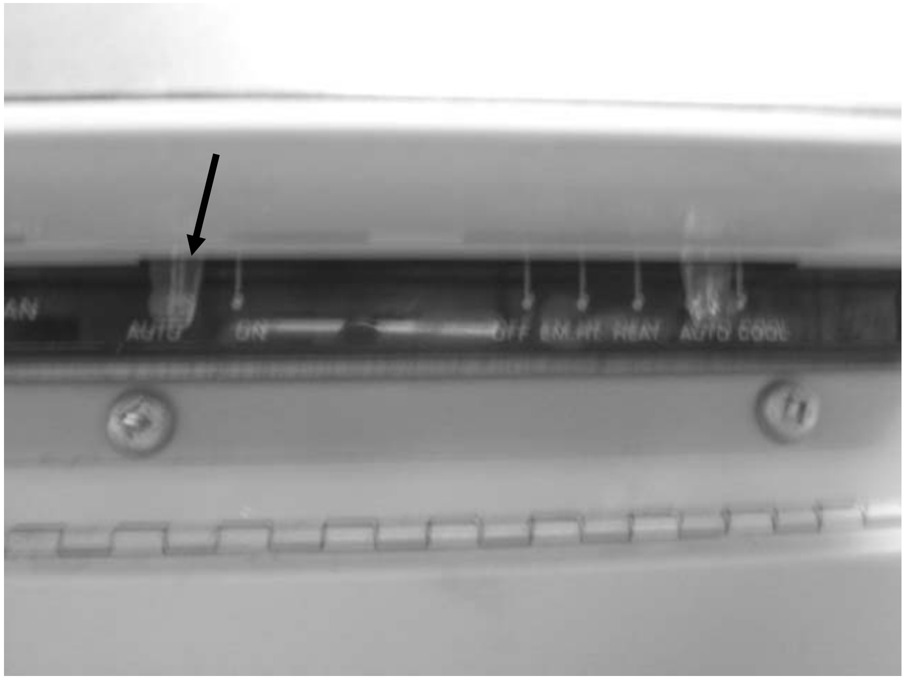
Picture 2

Ceiling-mounted supply diffuser for modular classroom

Picture 3

Ceiling-mounted return for modular classroom

Picture 4



AHU thermostat fan set to ‘auto’

Picture 5

Water-stained ceiling tiles

Picture 6

Water-damaged ceiling plaster

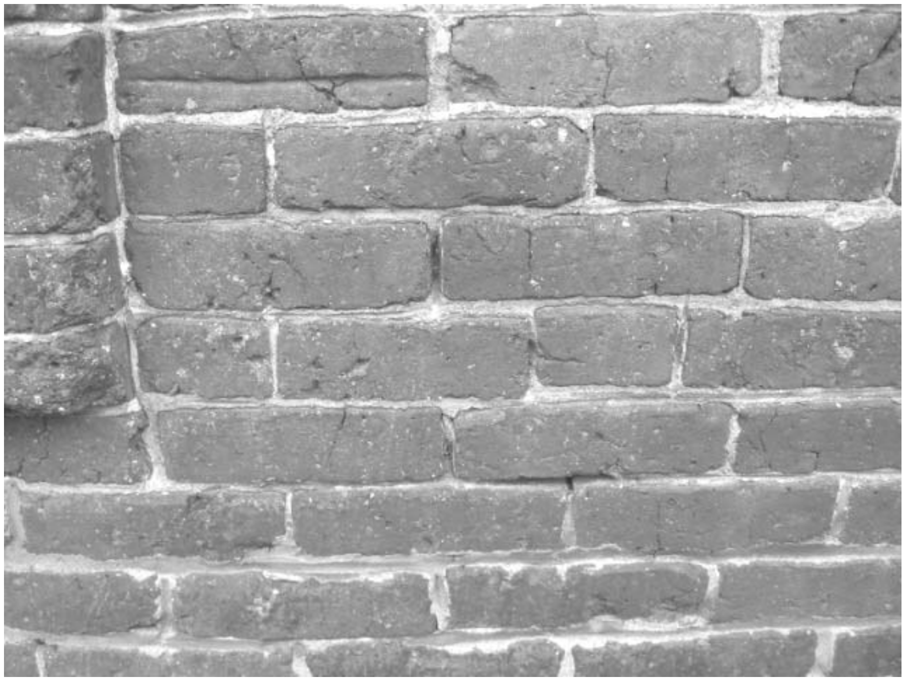
Picture 7

Water-damaged wall plaster

Picture 8

Damaged rubber gasket in window frame

Picture 9



Breaches in exterior wall

Picture 10

Breaches around window

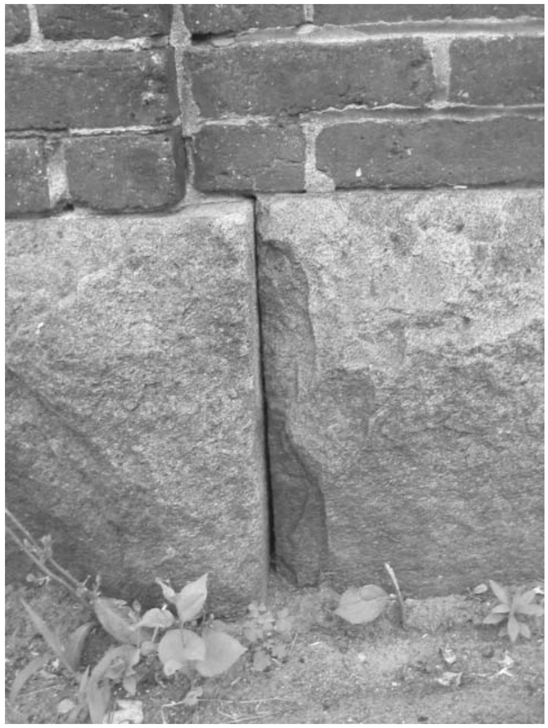
Picture 11

Damaged exterior wall to modular classrooms

Picture 12

Downspout with missing components, note water stains to exterior wall

Picture 13



Plants growing against building

Picture 14

Plants growing in subterranean pit

Bennett School | **Indoor Air Results**

145 Pleasant Street, Leominster, MA 01453 | **Date: 6/14/2005**

Table 1

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Background		82	69	437	ND	ND	86				approximately 20 cars passing per minute.
1	0	83	67	463	ND	ND	82	Y # open: 2 # total: 5	N	Y wall	Hallway DO, PF.
2 (office)	3	82	67	482	ND	ND	80	Y # open: 2 # total: 5	N	Y wall	window-mounted AC, DEM, laminator.
3	5	83	66	494	ND	ND	80	Y # open: 5 # total: 5	N	Y wall	PF.
4 OT/PT	0	83	65	468	ND	ND	86	Y # open: 5 # total: 5	N	N	Hallway DO, WD-CP, PF.
5	0	86	62	463	ND	ND	82	Y # open: 4 # total: 5	N	Y wall	Hallway DO, Inter-room DO, DEM, PF, FC re-use.
6	14	87	65	854	ND	ND	90	Y # open: 4 # total: 5	N	N	Hallway DO, Inter-room DO, DEM, PF.

ppm = parts per million
µg/m3 = micrograms per cubic meter

AD = air deodorizer
AP = air purifier
aqua. = aquarium

AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile

NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings

sci. chem. = science chemicals
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
VL = vent location
WP = wall plaster

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

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145 Pleasant Street, Leominster, MA 01453 | **Date: 6/14/2005**

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Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
7	5	87	70	647	ND	ND	98	Y # open: 3 # total: 5	N	N	Hallway DO, CD, PF, cleaners, items.
8	12	86	71	619	ND	ND	96	Y # open: 4 # total: 5	N	Y wall	Hallway DO, CD, PF.
ABA supervisor	0	83	67	481	ND	ND	85	N	N	N	Hallway DO,
bathroom	0	84	77	709	ND	ND	104	Y # open: 0 # total: 2	N	Y wall	Hallway DO
Nurse	0	83	65	482	ND	ND	82	Y # open: 1 # total: 1	N	N	Inter-room DO, PF.
occupational therapy	0	84	64	579	ND	ND	89	Y # open: 1 # total: 1	N	N	Hallway DO
school psychologis t	0	84	63	572	ND	ND	82	Y # open: 1 # total: 1	N	N	Hallway DO, PF.

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									Supply	Exhaust	
speech	0	86	63	524	ND	ND	88	Y # open: 1 # total: 1	N	N	Hallway DO, PF.
speech therapy	1	84	47	772	ND	ND	69	Y # open: 0 # total: 1	N	Y ceiling	window-mounted AC, WD-CP around pipe.`
portable (bathroom)	0	71	51	1241	ND	ND	41	N	Y ceiling	Y ceiling	Hallway DO, WD-wall.
portable (left)	16	73	48	1201	ND	ND	38	Y # open: 0 # total: 2	Y ceiling	Y ceiling	#WD-CT: 2, FC re-use.
portable (right)	20	76	54	1233	ND	ND	52	Y # open: 0 # total: 3	Y ceiling	Y ceiling	#WD-CT: 2, food use/storage.

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